Subject:...................... / /

d)

$I_{ch} = J\,W\,C\,V$

$I_{ch} = J * 2\pi * 60 * 11.76*10^{-9}\,\frac{F}{Km} * \frac{220*10^{3}}{\sqrt{3}}$

$\boxed{I_{ch} = J\,0.5631\ A/Km}$

or

$\boxed{I_{ch}\ 0.5631\ \angle 90^{\circ}\ A/km}$

e) $Q_{3\phi} = \sqrt{3}\,V_{LL}\,I$

$Q_{1\phi} = V_{ph}\,I$

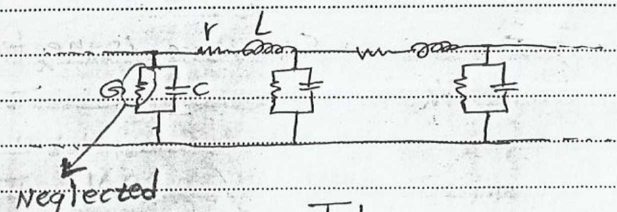
$Q_{3\phi} = 3\,Q_{1\phi}$

$\therefore\ Q_{3\phi} = \sqrt{3} * 220*10^{3} * 0.563*10^{-3} = 214.6\ VAR$

(1)

Subject:...................... / /

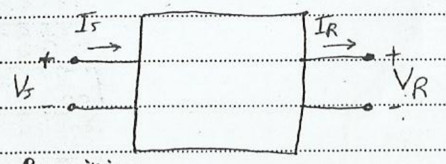
Transmission Line Modeling:



T.L

Short T.L | Medium | Long

$< 80Km$ | $80K < L \leq 240Km$ | $> 240Km$



Sending Voltage

Receiving Voltage

$V_s = A * V_R + B * I_R$

Receiving Current

$I_s = C * V_R + D\,I_R$

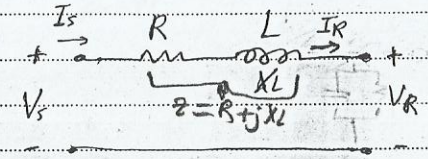
Sending Current

A, B, C, D → T.L constants or parameters

(2)

Subject:........................ / /

Short Line Model :



Capacitance is neglected

$V_s = V_R + Z I_R$; $A = 1$, $B = Z$

$I_s = I_R$; $C = 0$, $D = 1$

Voltage regulation %VR

$$\% VR = \frac{|V_{R(NL)}| - |V_{R(full\ load)}|}{|V_{R(FL)}|} * 100$$

$V_{R(NL)} \rightarrow$ Receiving Voltage at No Load

$V_{R(FL)} \rightarrow$ " " " full "

$$\eta\% = \frac{P_o}{P_i} * 100 = \frac{P_R}{P_s} * 100$$

efficiency

at No Load . $I_R = 0$

$$\boxed{V_{R(NL)} = \frac{V_s}{A}}$$

Nominal Voltage

ject:........Rated " / /

Ex 8 $f = 60\,Hz$

A 220 KV , 3ϕ T.L is 40 Km , The resistance per phase is $0.15\ \Omega/Km$, and The inductance per phase is $1.3263\ mH/Km$. The Shunt Capacitance is ~~neglected~~ negligible . Use short Line Model to find the Voltage & power at Sending end, and The V.R , & η When The line is supplying 3ϕ Load of

ⓐ 381 MVA at 0.8 p.f lagging at 220 KV. $V_{R(LL)}$

ⓑ 381 MVA at 0.8 p.f ~~lagging~~ leading at 220 KV.

Solution

Notes

phase to nutral الجهد

أي جهد يعطى في السؤال line to line

و P يلي نعطي لـ 3ϕ

$V_s = A V_R + B I_R$

$I_s = C V_R + D I_R$

$R = 0.15 * 40 = 6\ \Omega$

$X_L = \omega L = 2\pi * 60 * 1.3263 * 10^{-3} * 40 = 20\ \Omega$

$\boxed{Z = R + jX_L = 6 + j20}$ $Z = 20.88\ \Omega \angle 73.3^\circ$

$A = 1$, $B = Z = 20.88\ \Omega \angle 73.3^\circ$, $C = 0$, $D = 1$

$V_R = \frac{220K}{\sqrt{3}} = 127\ KV \angle 0^\circ$

Subject:

$$\underbrace{S}_{\text{Apperent power}} = \overset{\text{active power}}{P} + j\,Q \rightarrow \text{Reactive power}$$

$$S = \sqrt{P^2 + Q^2} \qquad P.f = \frac{P}{S}$$

$$S_{3\phi(R)} = \sqrt{3}\, V_{LL(R)}\, I^*_{(R)} \quad , \quad S_{1\phi} = V_{ph}\, I^*$$

$$|I_R| = \frac{381}{\sqrt{3} * 220} = 1000\,A = 1\,KA$$

$$I_R = 1\,KA \angle -36.87^\circ$$

$$V_s = A V_R + B\, I_R$$

$$= 1 * 127K\angle 0 + 20.88 \angle 73.3^\circ * 1K\angle -36.87$$

$$V_s = 144.3\ KV \angle 4.928^\circ$$

$$|V_s|_{LL} = \sqrt{3} * 144.3 = 250\,KV$$

$$I_s = I_R = 1\,KA \angle -36.87^\circ$$

$$S_{3\phi(s)} = \sqrt{3}\, V_{s(LL)}\, I^*_{(s)}$$

$$S_{3\phi(s)} = \sqrt{3}\,(250k\angle 4.93)(1k \angle 36.87) = 433 \angle 41.8^\circ\ MVA$$

$$S_{3\phi(s)} = \underbrace{322.8}_{P_s\ MW} + j\,\underbrace{288.6}_{Q_s\ MVAR}\ MVA$$

$$|V_{R(NL)}| = \frac{V_s}{A} = \frac{250k}{1} = 250\,KV$$

$$\% V.R = \frac{250 - 220}{220} * 100 = 13.64\%$$

$$\eta\% = \frac{P_R}{P_s} * 100 = \frac{381 * 0.8}{322.8} * 100 = 94.42\%$$

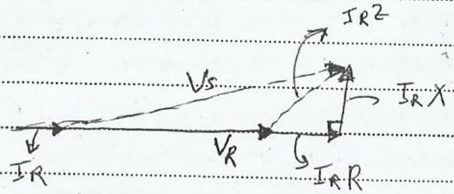
$$P_s = P_R + P_{losses} \rightarrow 3RI^2$$

$$P_{losses} = 18\,MW$$

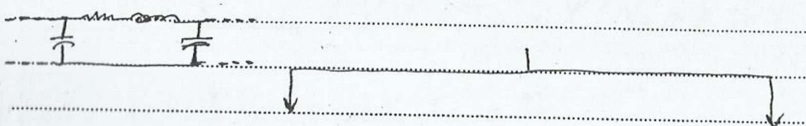
(b) $|V_s| = 210.26\ KV$

/ /

Unity power factor $P.F = 1$

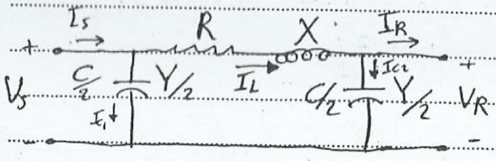


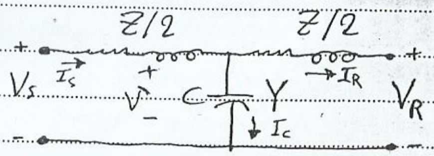
Medium Line Model : $[80km \leq L \leq 240 km]$



Π Model

T-Model





$Y = JWC$

$Y = \cancel{G} + jB_c$

0

Π- Model :

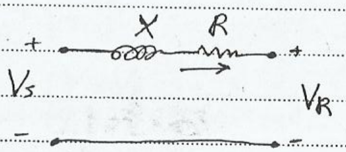
$V_s = A V_R + B I_R$

$I_s = C V_R + D I_R$

General equation

$V_s = V_R + Z I_L$

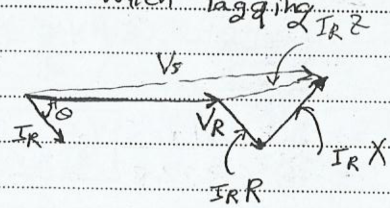
Subject:...................... / /



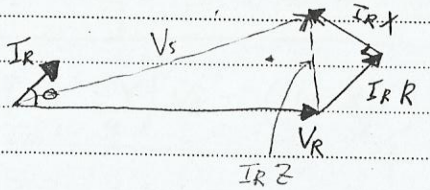
$V_s = V_R + Z I_R$

$= V_R + (R + JX) I_R = V_R + R I_R + J X I_R$

When lagging



When Leading



T-model:

$$A = D = 1 + \frac{ZY}{2}$$

$$B = Z\left(1 + \frac{ZY}{4}\right)$$

$$C = Y$$

$$I_s = I_c + I_R = YV' + I_R = Y\left(V_R + \frac{Z}{2} I_R\right) + I_R$$

$$I_s = YV_R + \frac{ZY}{2} I_R + I_R$$

$$\boxed{I_s = \underbrace{Y}_{C} V_R + \underbrace{\left(1 + \frac{ZY}{2}\right)}_{D} I_R}$$

$$V_s = \frac{Z}{2} I_s + YV'$$

$$\vdots$$

$$\boxed{V_s = \left(1 + \frac{ZY}{2}\right) V_R + Z\left(1 + \frac{ZY}{4}\right) I_R}$$

Subject: .... / /

Note: $A = D$ always / /

$$I_L = I_{C_2} + I_R$$

$$I_{C_2} = \frac{Y}{2} V_R$$

$$\therefore I_L = \cancel{Z} \frac{Y}{2} V_R + I_R$$

$$\therefore V_s = V_R + Z\left(\frac{Y}{2} V_R + I_R\right)$$

$$V_s = V_R + \frac{ZY}{2} V_R + Z I_R$$

$$\boxed{V_s = \left(1 + \frac{ZY}{2}\right) V_R + Z I_R}$$

$$\therefore \boxed{A = 1 + \frac{ZY}{2}} \qquad \boxed{B = Z}$$

$$I_s = I_{C_1} + I_L = \frac{Y}{2} V_s + \frac{Y}{2} V_R + I_R$$

$$I_s = \frac{Y}{2}\left[\left(1 + \frac{ZY}{2}\right) V_R + Z I_R\right] + \frac{Y}{2} V_R + I_R$$

$$\boxed{I_s = Y\left(1 + \frac{ZY}{4}\right) V_R + \left(1 + \frac{ZY}{2}\right) I_R}$$

$$\therefore \boxed{C = Y\left(1 + \frac{ZY}{4}\right)} \qquad \boxed{D = \left(1 + \frac{ZY}{2}\right)}$$

Subject:......................

Ex: A 345 KV, 3Ø, T.L is 130 km Long. The resistance per phase is 0.036 Ω/km and the inductance is 0.8 mH/km, The Shunt Capacitance is 0.0112 μf/km. The receiving Load is 270 MVA With 0.8 P.f Lagging at 325 KV. Use the medium line model to find the Voltage & power at Sending end and The V.R. f = 60 Hz.

Solution

$R = 0.036\ \Omega/km * 130\ km = 4.68\ \Omega$

$X_L = \omega L = 2\pi * 60 * 0.8 * 10^{-3} * 130 = 39.207\ \Omega$

$Z = 4.68 + J\,39.207 = 39.5 \angle 83.2^\circ\ \Omega$

$Y = \cancel{G} + JB = J * 2 * \pi * 60 * 0.0112 * 10^{-6} * 130 = 0.000549 \angle 90\ S$

$A = (1 + \frac{ZY}{2}) = 0.989 \angle 0.07^\circ$

$B = Z = 39.5 \angle 83.2^\circ\ \Omega$

$C = Y(1 + \frac{ZY}{4}) = 5.460 * 10^{-4} \angle 90.04^\circ\ S$

$D = A = 0.989 \angle 0.07^\circ$

$S_{3\phi} = \sqrt{3}\, V_{LL} * I_S^*$

Refrence

$V_R = \frac{325\,KV}{\sqrt{3}} \angle 0^\circ = 187.64\,KV \angle 0^\circ$

$I_R = \frac{S}{\sqrt{3} V_R} = \frac{270 * 10^6}{\sqrt{3} * 325 * 10^3} = 479.64\,A \angle -36.87^\circ$

$V_S = A V_R + B I_R = 199.15\,KV \angle 4.01^\circ$

$I_S = C V_R + D I_R = 421.37\,A \angle -25.32^\circ$

$\boxed{|V_S|_{LL} = \sqrt{3}\, V_S = 344.94\,KV}$

$S_{3\phi} = \sqrt{3}\, V_{S(LL)}\, I^*_{(S)} = \sqrt{3}\,(344.94\,KV \angle 4.01^\circ)(421.37 \angle 25.32^\circ)$

$\boxed{S_{3\phi} = \underbrace{219478051.5}_{P[W]} + j\,\underbrace{123316490.8}_{Q[VAR]}}\ VA$

$V.R\% = \frac{|V_{R(NL)}| - |V_{R(FL)}|}{|V_{R(FL)}|} * 100$

$|V_{R(NL)}| = \frac{V_S}{A}\Big|_{I_R = 0} = 348.78\,KV$

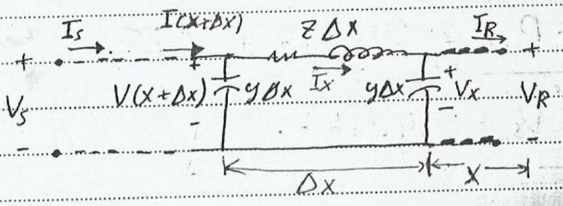
$|V_{R(FL)}| = 325\,KV$

$\boxed{\therefore V.R\% = \left(\frac{348.78 - 325}{325}\right) * 100 = 7.317\%}$

Subject:

Long Line Model: $\geq 240\,Km$

For Short & medium Line, The Line parameters are assumed Lumped « Not high accurate » For long line The exact effect of the distributed parameters must be considered. The expression of Voltage & current at any point on the line are derived, Then based on These equations an equivalent π model is obtained



$z \triangleq$ Series impedance / unit length

$y \triangleq$ Shunt admittance / unit length

Consider a small segment of line Δx at distance x from The receiving end of the line

$$V(x+\Delta x) = V(x) + z\,\Delta x\, I(x)$$

$$z\, I(x) = \frac{V(x+\Delta x) - V(x)}{\Delta x}$$

$$\lim_{\Delta x \to 0} \frac{V(x+\Delta x) - V(x)}{\Delta x} = \frac{dV(x)}{dx}$$

$$\boxed{\frac{dV(x)}{dx} = z\, I(x)} \longrightarrow \boxed{1}$$

$$I(x+\Delta x) = I(x) + y\,\Delta x\, V(x+\Delta x)$$

$$\Delta x \to 0$$

$$\frac{I(x+\Delta x) - I(x)}{\Delta x} = y\, V(x+\Delta x)$$

$$\boxed{\frac{dI(x)}{dx} = y\, V(x)} \longrightarrow \boxed{2}$$

$$\frac{d^2V(x)}{dx^2} = z\,\frac{dI(x)}{dx}$$

$$\frac{d^2V(x)}{dx^2} = z\, y\, V(x)$$

$$\frac{d^2V(x)}{dx^2} - zy\, V(x) = 0$$

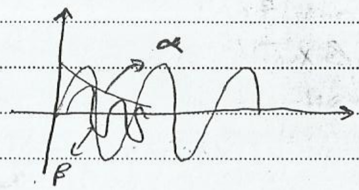
propagation constant $\gamma = \sqrt{zy} = \alpha + j\beta$ → phase constant

attenuation constant

$$\boxed{\frac{d^2V(x)}{dx} - \gamma^2 V(x) = 0} \longrightarrow \boxed{3}$$

Subject:......................

$$V_s = A V_R + B I_R$$



$$\boxed{V(x) = A_1 e^{\gamma x} + A_2 e^{-\gamma x}} \longrightarrow \boxed{4}$$

$$\boxed{I(x) = \frac{1}{Z}\frac{dV(x)}{dx} = \frac{\gamma}{Z}\left[A_1 e^{\gamma x} - A_2 e^{-\gamma x}\right]} \longrightarrow \boxed{5}$$

$$= \frac{1}{Z}\gamma A_1 e^{\gamma x} - \gamma A_2 e^{-\gamma x}$$

$$I(x) = \frac{\cancel{\gamma} 1}{Z_c}\left[A_1 e^{\gamma x} - A_2 e^{-\gamma x}\right]$$

$Z_c \longrightarrow$ characteristic Impedance $\qquad Z_c = \sqrt{\frac{Z}{y}}$

To find A_1 & A_2

at $x = 0 \longrightarrow V(x) = V_R$
$I(x) = I_R$

$$A_1 = \frac{V_R + Z_c I_R}{2} \quad , \quad A_2 = \frac{V_R - Z_c I_R}{2}$$

/ /

$$V(x) = \left[\frac{V_R + Z_c I_R}{2}\right] e^{\gamma x} + \left[\frac{V_R - Z_c I_R}{2}\right] e^{-\gamma x}$$

$$I(x) = \frac{1}{Z_c}\left\{\left[\frac{V_R + Z_c I_R}{2}\right] e^{\gamma x} - \left[\frac{V_R - Z_c I_R}{2}\right] e^{-\gamma x}\right\}$$

$$V(x) = \underbrace{\left(\frac{e^{\gamma x} + e^{-\gamma x}}{2}\right)}_{\text{Cosh}(\gamma x)} V_R + Z_c \underbrace{\left(\frac{e^{\gamma x} - e^{-\gamma x}}{2}\right)}_{\text{Sinh}(\gamma x)} I_R$$

$$I(x) = \frac{1}{Z_c}\,\frac{e^{\gamma x} - e^{-\gamma x}}{2}\, V_R + \frac{e^{\gamma x} + e^{-\gamma x}}{2}\, I_R$$

$$V(x) = \underbrace{\left[\text{Cosh}(\gamma x)\right]}_{A} V_R + \underbrace{\left[Z_c \,\text{Sinh}(\gamma x)\right]}_{B} I_R$$

$$I(x) = \underbrace{\left[\frac{1}{Z_c}\,\text{Sinh}(\gamma x)\right]}_{C} V_R + \underbrace{\left[\text{Cosh}(\gamma x)\right]}_{D} I_R$$

$$\boxed{A = \text{Cosh}(\gamma x)} \qquad \boxed{B = Z_c \,\text{Sinh}(\gamma x)}$$

$$\boxed{C = \frac{1}{Z_c}\,\text{Sinh}(\gamma x)} \qquad \boxed{D = \text{Cosh}(\gamma x)}$$

$$\frac{\acute{Y}}{2} = \frac{1}{Z_c}\overbrace{\left(\frac{\cosh(\gamma L) - 1}{\sinh(\gamma L)}\right)}^{\tanh\left(\frac{\gamma L}{2}\right)} = \frac{1}{Z_c}\tanh\left(\frac{\gamma L}{2}\right)$$

$$\boxed{\frac{\acute{Y}}{2} = \frac{1}{Z_c}\tanh\left(\frac{\gamma L}{2}\right) = \frac{Y}{2}\,\frac{\tanh\left(\frac{\gamma L}{2}\right)}{(\gamma L/2)}}$$

unit per length

$$Z_c = \frac{\sqrt{z}}{\sqrt{y}} \times \frac{\sqrt{z}}{\sqrt{z}} \times \frac{L}{L} = \frac{Z}{\gamma L}$$

total

$$\boxed{\gamma = \sqrt{zy}} \qquad \boxed{Z = zL}$$

$$\boxed{Z_c = \frac{Z}{\gamma L}}$$

Voltage & current Waves:

$$\gamma = \alpha + J\beta$$

Velocity of propagation ← $V = \frac{W}{\beta}$

Wave length ← $\lambda = \frac{2\pi}{\beta}$

Subject: .... / /

at $X = L$

$$V(x) = V(L) = V(s)$$
$$I(x) = I(L) = I(s)$$

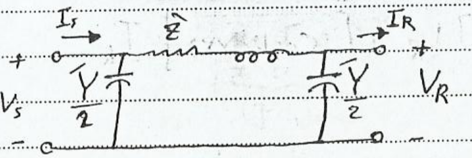
$$V_s = \left[\cosh(\gamma L)\right] V_R + \left[Z_c \sinh(\gamma L)\right] I_R$$

$$I_s = \left[\frac{1}{Z_c}\sinh(\gamma L)\right] V_R + \left[\cosh(\gamma L)\right] I_R$$

Note:

$$\boxed{AD - BC = 1}$$

Equivalent Circuit of Long Line:



$A = D = 1 + \frac{ZY}{2}$

$B = Z$

$C = Y\left(1 + \frac{ZY}{4}\right)$

$$\boxed{\acute{Z} = Z_c \sinh(\gamma L) = Z\,\frac{\sinh(\gamma L)}{\gamma L}}$$

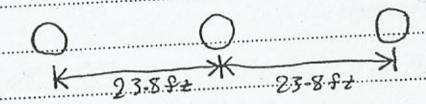
$$A = 1 + \frac{\acute{Z}\acute{Y}}{2} = \cosh(\gamma L)$$

$$1 + \frac{Z_c \sinh(\gamma L) \cdot \acute{Y}}{2} = \cosh(\gamma L)$$

Subject:..................

Example:

A Single circuit 3Ø 60Hz T.L is 230mi Long. The conductors are Rook With flat horizontal Spacing 23.8 ft between Conductors. The load on The lines is 125MW at 215 KV With 100% p.f. Find the Sending end quantities & % V.R, Also find The Wave length & Velocity of propagation of the line.



Solution

$Z = r + jX_L$ from Table

$r = 0.1603$

$X_L = X_a + X_d = 0.415 + 0.4127$

$Z = 0.1603 + j0.8277$ Ω/mi

$$y = j\frac{1}{(\underset{X_a}{0.095} + \underset{X_d}{0.1009})*10^6} = 5.105*10^{-6}\angle 90^\circ \ \ S/mi$$

$$\gamma L = 230\sqrt{0.8431*5.105*10^{-6}}\ \angle\frac{79.04+90}{2}$$

$\gamma L = 0.4772\ \angle 84.52^\circ$

$$\gamma L = \underset{\alpha L}{0.0456} + j\underset{\beta L}{0.4750}$$

$$A = \cosh(\gamma L) = \frac{e^{\gamma L} + e^{-\gamma L}}{2}$$

$$e^{\gamma L} = e^{\alpha L}\angle\beta L = e^{0.0456}\angle 27.22^\circ$$

$$e^{-\gamma L} = e^{-0.0456}\angle -27.22^\circ$$

$$\boxed{A = 0.8904\ \angle 1.3427^\circ}$$

$B = Z_c \sinh(\gamma L)$

$$Z_c = \sqrt{\frac{Z}{y}} = \sqrt{\frac{0.4772}{5.105*10^{-6}}}\ \angle\frac{79.04-90}{2} = 406.4\ \angle -5.48\ \Omega$$

$$\sinh(\gamma L) = \frac{e^{\gamma L} - e^{-\gamma L}}{2} = 0.4597\ \angle 84.93^\circ$$

$$\boxed{B = 186.82\ \angle 79.45^\circ}$$

$$V_R = \frac{215}{\sqrt{3}} = 124.13\angle 0 \ \ KV$$

$$I_R = \frac{125}{\sqrt{3}*215*1} = 335.7\angle 0$$

$P_{3\phi} = \sqrt{3}\ V_{LL}\ I\ \cos\theta$

line 8

for long model

$z = \cancel{r} + jwL$

$y = \cancel{g} + jb = j\,wc$

$\gamma = \sqrt{zy} = \cancel{\alpha} + j\beta$

$\boxed{\gamma = j\beta = jw\sqrt{LC}}$

$\boxed{A = \cos(\beta L)}$

$\boxed{B = jZ_c \sin(\beta L)}$

$\boxed{C = \frac{1}{Z_c} j \sin(\beta L)}$

$\boxed{D = A}$

$\boxed{Z_c = \sqrt{\frac{z}{y}} = \sqrt{\frac{L}{C}}}$

$\cosh(\gamma L) = \cosh(j\beta L) = \cos(\beta L)$

$\sinh(\gamma L) = \sinh(j\beta L) = j\sin(\beta L)$

$V_s = \cos(\beta L)\, V_R + j\, Z_c \sin(\beta L)\, I_R$

$I_s = j\frac{1}{Z_c}\sin(\beta L) V_R + \cos(\beta L)\, I_R$

$I_s = \frac{1}{Z_c}\sinh(\gamma L)$

For Typical T.L Z_c Varies from 400Ω for 69KV
→ 250Ω for Double circuit 765 KV

Subject:.........

$V_s = AV_R + BI_R = 137.86 \angle 27.77$ KV

$|V_s|_{LL} = \sqrt{3}\,(137.86) = 238.8$ KV

$I_s = CV_R + DI_R = \frac{1}{Z_c}\sinh(\gamma L) V_R + \cosh(\gamma L) I_R$

$= 332.31 \angle 26.33$ A

$P_f = \cos(27.77 - 26.33) = 0.9997 \simeq 1$

$S_{3\phi} = \sqrt{3}\, V_{s_{LL}}\, I_s^* = \underset{P}{137400437.2} + j\underset{Q}{3453976.9}$

$\beta = \frac{\beta L}{L} = \frac{0.475}{230} = 0.002065$ rad / mi

$\lambda = \frac{2\pi}{\beta} = \frac{2*3.14}{0.002065} = 3043$ mi

$V = f\lambda = 60 * 3043 = 182.580$ mi/s

Subject:...................... / /

Saadat 5-5 8D

ex: A 3ϕ, 60Hz, 500 KV T.L is 300 Km long, The Line inductance is 0.97 mH/Km/ph & its capacitance is 0.0115 μf/Km/ph. Assume loss less Line

a) Determine β, Z_c, V, λ

b) The receiving end rated load is 800 MW, 0.8 P.f lagging at 500 KV, Determine The sending end quantities & %VR

Solution

$\beta = W\sqrt{LC} = 2\pi f\sqrt{LC}$

$\beta = 2\pi(60)\sqrt{0.97*10^{-3} * 0.0115*10^{-6}} = 1.259*10^{-3}$ rad/km

$Z_c = \sqrt{\frac{L}{C}} = \sqrt{\frac{0.97*10^{-3}}{0.0115*10^{-6}}} = 290.43\ \Omega$

$V = \frac{W}{\beta} = \frac{2\pi(60)}{(1.259*10^{-3})} = 299436.9$ Km/S

$\lambda = \frac{2\pi}{\beta} = 4990.6$ Km

$V = \frac{1}{\sqrt{LC}}$, $\lambda = \frac{V}{f}$

/ / Subject:......................

$P = 800$ MW $P_f = 0.8$ lagging

$V_{R_{LL}} = 500$ KV

$A = \cos(\beta L) = \cos\left(1.259*10^{-3} * 300 * \frac{180}{\pi}\right)$

$\boxed{A = 0.9295}$

$B = J Z_c \sin(\beta L) = J(290.43)\sin\left(1.259*10^{-3}*300*\frac{180}{\pi}\right)$

$\boxed{B = J\,107.1}$

$C = J\frac{1}{Z_c}\sin(\beta L)$

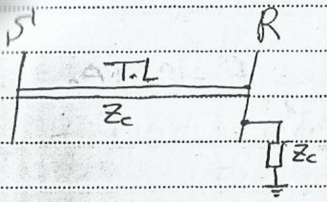
$\boxed{C = J\,1.2698*10^{-3}}$

$\boxed{A = D = 0.9295}$

$V_{R_{ph}} = 288.7\text{KV}\angle 0^\circ$

$I_R = \frac{800M}{\sqrt{3} * 500K * 0.8} = 1.155\ \text{KA}\angle -36.87^\circ$

Impedance Loading : $S'IL$



The load Corresponding to Z_c at V_{rated} is Knew as $S'IL$

$$S'IL = 3\, V_{R_{ph}} I_R^* = 3 \frac{|V_R|^2}{Z_c} = \frac{|V_{rated\,L\text{-}L}|^2}{Z_c}$$

$$I_R = \frac{V_R}{Z_c}$$

$$S'IL = \frac{|V_{Rated\,(L-L)}|^2}{Z_c} \quad [MW]$$

$$V_s = \cos(\beta L) V_R + J Z_c \sin(\beta L)\, I_R$$

$$V_s = \cos(\beta L) V_R + J \cancel{Z_c} \sin(\beta L) \frac{V_R}{\cancel{Z_c}}$$

$$V_s = V_R \left[\cos(\beta L) + J \sin(\beta L) \right]$$

$$\boxed{V_s = V_R \angle \beta L}$$

Subject:.......................

$$V_s = A V_R + B I_R = 356.6\ KV \angle 16.11^\circ$$

$$V_{s_{LL}} = 617.6\ KV \angle 16.11^\circ$$

$$I_s = C V_R + D I_R = 0.9026\ KA \angle -17.9^\circ$$

$$P_f = \cos(16.11^\circ + 17.9^\circ) = 0.829 \text{ lagging}$$

$$S' = \sqrt{3}\, V_{LL} I_s^* = (\underset{\substack{P \\ MW}}{800.4} + j \underset{\substack{Q \\ MVAR}}{540.1})\ MVA$$

$$V.R = \frac{|V_{NL}| - |V_{FL}|}{|V_{FL}|}$$

$$|V_{NL}| = \frac{|V_s|}{A} = \frac{|617.6K|}{0.9295} = 664.4\ KV$$

$$V.R = \frac{664.4 - 500}{500} = 0.3289$$

$$V.R\% = 32.89\%$$

Subject:......................

Complex Power flow ~~T~~ Through T.L :-

$$A = |A| \angle \theta_A \quad , \quad B = |B| \angle \theta_B$$

$$V_s = |V_s| \angle \delta \quad , \quad V_R = |V_R| \angle 0$$

$$V_s = A V_R + B I_R$$

$$I_R = \frac{V_s - A V_R}{B} = \frac{|V_s| \angle \delta}{|B| \angle \theta_B} - \frac{|A| \angle \theta_A * |V_R| \angle 0}{|B| \angle \theta_B}$$

$$I_R^* = \frac{|V_s|}{|B|} \angle \theta_B - \delta - \frac{|A| |V_R|}{|B|} \angle \theta_B - \theta_A$$

$$S_{R(3\phi)} = \frac{3 |V_s| |V_R|}{|B|} \angle \theta_B - \delta - \frac{3 |A| |V_R|^2}{|B|} \angle \theta_B - \theta_A$$

$$\boxed{S_{R(3\phi)} = \frac{|V_{s(L-L)}| \, |V_{R(L-L)}|}{|B|} \angle \theta_B - \delta - \frac{|A| |V_{R(L-L)}|^2}{|B|} \angle \theta_B - \theta_A}$$

$$S_{R(3\phi)} = 3 V_R I_R^* = P_{R(3\phi)} + J \, Q_{R(3\phi)}$$

$$P_{R3\phi} = \frac{|V_{s(L-L)}| \, |V_{R(L-L)}|}{|B|} \cos(\theta_B - \delta) - \frac{|A| |V_{R(L-L)}|^2}{|B|} \cos(\theta_B - \theta_A)$$

$$Q_{R3\phi} = \frac{|V_{s(L-L)}| \, |V_{R(L-L)}|}{|B|} \sin(\theta_B - \delta) - \frac{|A| |V_{R(L-L)}|^2}{|B|} \sin(\theta_B - \theta_A)$$

for lossline

$$\theta_A = 0 \qquad \theta_B = 90 \qquad B = J \bar{X} = J \underbrace{Z_c \sin(\beta L)}_{\bar{X}}$$

$$\cos(90 - \delta) = \sin(\delta)$$

$$P_{R(3\phi)} = \frac{|V_s|_{LL} * |V_R|_{LL}}{|B|} \sin(\delta)$$

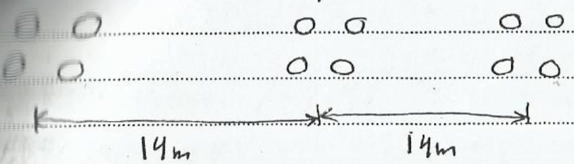
$$\sin(90 - \delta) = \cos(\delta)$$

$$Q_{R(3\phi)} = \frac{|V_s|_{LL} * |V_R|_{LL}}{\bar{X}} \cos(\delta) - \frac{|A| |V_R|_{LL}^2}{\bar{X}}$$

or $|B|$

$$\bar{X} = |B| = Z_c \sin(\beta L)$$

terminated in a purely resistive load. Determine The S.E quantities & VR When The receiving end load is ~~...~~ 264.5 Ω at 735 kV



* Solution *

a) $GMD = \sqrt[3]{14 * 14 * 28} = 17.64\ m$

$GMR_L = 1.09 \sqrt[4]{1.439 * 45^3} = 20.74\ cm$

$GMR_c = 1.09 \sqrt[4]{1.812 * 45^3} = 21.97\ cm$

$L = 2 * 10^{-7} \ Ln\left(\frac{GMD}{GMR_L}\right) = 8.89 * 10^{-7}\ H/m$

$C_n = \frac{2\pi \epsilon_0}{Ln\left(\frac{GMD}{GMR_c}\right)} = 12.67 * 10^{-12}\ F/m$

$Z_c = \sqrt{\frac{L}{C}} = 264.9\ \Omega$

$\beta = W\sqrt{LC} = 1.2652 * 10^{-6}\ rad/m$

$\lambda = \frac{2\pi}{\beta} = 4.966 * 10^{6}\ m = = 4966\ Km$

$SIL = \frac{|V_{rated\ LL}|^2}{Z_c} = \frac{(765K)^2}{264.9} = \cancel{\dots}$

$= 2209.2\ MW$

Subject:......................

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$AD - BC = 1$$

$$\begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} D & -B \\ -C & A \end{bmatrix} \begin{bmatrix} V_s \\ I_s \end{bmatrix}$$

$V_R = D V_s - B I_s$

@ $V_s \angle 0$

$I_R = -C V_s + A I_s$

Problem 5-8:

A 3Ø 765 KV, 60 Hz transposed Line is composed of 4 ACSR, 1,430,000 cmil, 45/7 Bobo link Cond./ph With flat horizontal Spacing of 14m, The Cond. have diameter of 3625 cm & GMR of 1.439 cm The bundle Spacing is 45 cm, The line is 400 km long - Assume lossless line

a) Calculate Z_c, β, λ, SIL, ABCD Constant

b) The line delivers 2000 MVA at 0.8 lagging P.F at 765 kV Determine The S.E quantities & VR.

c) Determine The R.E quantities When 1920 MW & 600 MVAR are being trasmitted at 765 kV @ The Sending end.

$V_s = 514.82\,kV \angle 18.15^\circ$

$I_s = 1.1\,KA \angle -2.43^\circ$

$|V_{s_{LL}}| = 896.9\,KV$

$S'_{3\phi} = \sqrt{3}\, V_{LL}\, I_s^*$

$S'_{3\phi} = \sqrt{3} * 896.9K \angle 18.15 * 1.1K \angle 2.43$

$S'_{3\phi} = (\overset{1600}{\cancel{1583.1}} + j\,\overset{601.5}{\cancel{896.2}})$ MVA

$P_{sending} = P_{receiving}$ lossless Line

c) $S'_{3\phi_s} = (1920 + j600)$ MVA

$V_{s_{LL}} = 765\,KV \angle 0^\circ$

$V_R = DV_s - BI_s$

$I_R = -CV_s + AI_s$

$V_{s_{ph}} = \dfrac{765\,kV}{\sqrt{3}} = 441.67\,KV \angle 0^\circ$

$S_{3\phi_{(s)}} = 2011.56\,MVA \angle 17.35$

$I_s = 1518.1\,A \angle -17.35^\circ$

Subject:.......................

$A = \cos(\beta L) = \cos(1.2652 * 10^{-6} * 400 * 10^3 * \frac{180}{\pi})$

$\boxed{A = \cos(28.99) = 0.8747}$

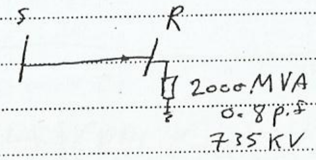
$B = J\, Z_c \sin(\beta L) = J(264.9) \sin(28.99)$

$\boxed{B = J\,128.39}$

$\boxed{C = J\,\dfrac{1}{Z_c}\sin(\beta L) = J\,1.833 * 10^{-3}}$

$\boxed{D = A = 0.8747}$

b)



$V_s = AV_R + BI_R$

$V_R = \dfrac{735\,KV}{\sqrt{3}} = 424.35 \angle 0^\circ$

$I_R = \dfrac{S'}{\sqrt{3}\, V_{LL}} = \dfrac{2000}{\sqrt{3} * 0.735} = 1571.02\,A \angle -36.87^\circ$

Subject: .... / /

$$= 3V_R I_R^* = 1978.86 \text{ MVA } \angle 14^\circ$$

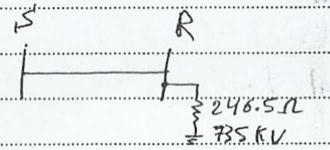
$$= 1920 \text{ MW} + j\, 479.2 \text{ MVAR}$$

$$\% VR = \frac{V_{RNL} - V_{RFL}}{V_{RFL}} * 100$$

$$|V_{RNL}| = \frac{|V_s|_{LL}}{A} = 874.69 \text{ kV}$$

$$\% VR = \frac{|874.69| - |653.33|}{|653.33|} * 100 = 33.88\%$$

d)



$$V_R = \frac{735 \text{ kV}}{\sqrt{3}} = 424.35 \angle 0 \text{ kV}$$

$$I_R = \frac{V_R}{R} = \frac{424.35 * 10^3}{264.5} = 1.604 \text{ kA} \angle 0$$

$$I_s = 1.604 \text{ kV } \angle 29^\circ$$

$$V_s = 424.48 \text{ kV } \angle 29.02^\circ$$

Subject: .... / /

اشتقاق

$$V_R = DV_s - BI_s$$

$$I_s = \frac{DV_s - V_R}{B} = \frac{|A| \angle\theta_A \, |V_s| \angle\delta}{|B| \angle\theta_B} - \frac{|V_R| \angle 0}{|B| \angle\theta_B}$$

$$I_s^* = \frac{|A|\,|V_s|}{|B|} \angle \theta_B - \theta_A - \delta - \frac{|V_R|}{|B|} \angle\theta_B$$

$$S_{3\phi(s)} = 3V_s I_s^* = \frac{3\,|A|\,|V_s|^2}{|B|} \angle\theta_B - \theta_A - \frac{3|V_R||V_s|}{|B|} \angle\delta + \theta_B$$

$$S_{3\phi(s)} = \frac{|A|\,|V_s|_{LL}^2}{|B|} \angle\theta_B - \theta_A - \frac{|V_R|_{LL}\,|V_s|_{LL}}{|B|} \angle\delta + \theta_B$$

$$V_R = (0.8747)(441.67\angle 0) - (128.8\angle 90)(1.518 \angle -17.35)$$

$$V_R = 377.2 \angle -29.54 \text{ kV}$$

$$|V_R|_{LL} = \sqrt{3} * 377.2 = 653.33 \text{ kV}$$

$$I_R = -CV_s + AI_R = 1.749 \text{ kA } \angle -43.35^\circ$$

/ /

$\boxed{V_{rated} = V_{Base}} \rightarrow$ in this case

$V_s = 230\ kV \quad , \quad V_{rated} = 220\ kV$

$V_{p.u} = \frac{230}{220} = 1.045\ p.u$

From ②

$$P_{R(3\phi)} = \frac{|V_s|_{LL}}{V_{rated(LL)}} * \frac{|V_R|_{LL}}{V_{rated}} * \frac{V_{rated}^2}{Z_c \sin(\beta l)} \sin(\delta)$$

$$\boxed{P_{R(3\phi)} = \frac{(V_{s(p.u)})(V_{R(p.u)})(SIL)}{\sin(\beta l)} \sin(\delta)}$$

Ex :-

A Three phase power 700 MW is to be trasmitted to a substation located 315 Km from The Source of power. for a perliminary line design assume The following parameters $V_s = 1$, $V_R = 0.9$ p.u

$\lambda = 5000$ km , $Z_c = 320\ \Omega$, $\delta = 36.87^\circ$. assume lossless line

a) Based on The practical line Loadability equation, determine The nominal Voltage level for The T.L.

b) for the transmission Voltage level obtained in (a) calculate the Theoretical maximum power That can be transferred by The T.L.

Subject:.................... / /

practical loadability line :

$$P_{R(3\phi)} = \frac{|V_s|_{LL}\,|V_R|_{LL}}{|B|} \cos(\theta_B - \delta) - \frac{|A|\,|V_R|_{LL}^2}{|B|} \cos(\theta_B - \theta_A) \rightarrow ①$$

$$P_{R(3\phi)} = \frac{|V_s|_{LL}\,|V_R|_{LL}}{|B|} \sin(\delta) \rightarrow ② \quad \text{lossless line}$$

* Theoretical Maximum Real Power occurs When $\theta_B = \delta$

Power Transmission Capability :

The power handling ability of a line is Limited by The Thermal loading limited by The Thermal Loading Limit Voltage Limit & Stability Limit.

$S_{Thermal}$ = Thermal Loading Limit = $3\, V_{\phi\, rated}\, I_{Thermal}$

For lossless line $\quad \bar{X} = Z_c \sin(\beta l)$

Eq② Will be

Per Unit System P.U :-

$$p.u = \frac{\text{Accual Value}}{\text{Base}}$$

Compensation :-

Shunt compensation | Series

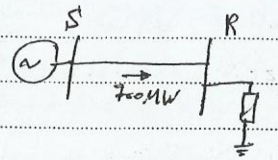
Reactor | Capacitor | Capacitor

To reduce Voltage | To increase Voltage

Subject: ....

Solution

a)



$$P_{3\phi} = \frac{|V_S|_{p.u} \, |V_R| \, (SIL)}{\sin\left(\frac{2\pi}{\lambda} L\right)} \sin(\delta)$$

$$700 = \frac{1 * 0.9 \, (SIL)}{\sin(22.68)} \sin(36.87)$$

$$SIL = 499.83 \, MW$$

$$SIL = \frac{|V_{rated}|^2}{Z_c} \rightarrow V_{rated} = \sqrt{(SIL)(Z_c)}$$

$$V_{\underset{nominal}{rated}} = 400 \, kV$$

b) When $\theta_R = \delta$; $\theta_R = 90$

$$P_{3\phi} = \frac{|V_S|_{LL} \, |V_R|_{LL}}{X} \sin(\delta)$$

$$P_{3\phi} = \frac{(400*1)\,(400*0.9)}{(320)\sin(22.68)} = 1167 MW$$

Subject: Tutorial

Glover / Prob 5-14 :

A 500 km , 500 kV , 60 Hz , 3ϕ T.L has $z = 0.03 + j0.35\ \Omega/km$

$y = j\,4.4 \times 10^{-6}\ S/km$

Calculate ① Z_c ② γL , ABCD

* Solution *

$Z = 0.3512 \angle 85.1^\circ$

$Y = 4.44 \times 10^{-6} \angle 90$

$$Z_c = \sqrt{\frac{Z}{Y}} = \sqrt{\frac{0.3531}{4.4 \times 10^{-6}}} \angle \frac{85.1 - 90}{2}$$

$$Z_c = 282.6 \angle -2.45^\circ$$

$$\gamma L = \sqrt{zy}\, L = \left(\sqrt{0.3531 \times 4.4 \times 10^{-6}}\right)(500) \angle \frac{85.1 + 90}{2}$$

$$\gamma L = 0.6216 \angle 87.55^\circ = \underset{(\alpha L)}{0.02657} + j\,\underset{(\beta L)}{0.6215}$$

$$A = \cosh(\gamma L) = \frac{e^{\gamma L} + e^{-\gamma L}}{2} = \frac{e^{\alpha L} \angle \beta L + e^{-\alpha L} \angle -\beta L}{2}$$

$$A = \frac{e^{0.02657} \angle 35.58 + e^{-0.02657} \angle -35.58}{2}$$

$$\boxed{A = \underset{|A|}{0.8137} \angle \underset{\theta_A}{1.09}}$$

$$\sinh(\gamma L) = \frac{e^{\alpha L} \angle \beta L - e^{-\alpha L} \angle -\beta L}{2} = 0.5825 \angle 87.87^\circ$$

$$B = Z_c \sinh(\gamma L) = (282.6 \angle -2.45^\circ)(0.5825 \angle 87.87^\circ)$$

$$\boxed{B = 164.6 \angle 85.42\ \Omega}$$

$$\boxed{C = \frac{1}{Z_c} \sinh(\gamma L) = 2.061 \times 10^{-3} \angle 90.33\ S}$$

$$\boxed{D = A = 0.8137 \angle 1.09^\circ}$$

Prob 5-23

Determine The equivalent π circuit for the line in prob 5-14 & compared with the nominal circuit π circuit

$$Z' = Z_c \sinh(\gamma L) = 164.6 \angle 85.42^\circ$$

OR

$$Z' = Z \frac{\sinh(\gamma L)}{\gamma L} = 164.6 \angle 85.42 = 13.14 + j\,164.1$$

$\underset{z}{(0.3513 \angle 85.1)}\ \underset{L}{(500)}$

Subject:.......................

5-38 :

The line in prob 5-16 has 3 ACSR 1113,000 cmil cond/ph. Calculate the theoretical max. real power that this line can be delivered & compare with thermal limit of the line. Assume $V_S = V_R = 1$ p.u & unity power factor at the receving end

Solution

$\theta_B = \delta$

$$P_{3\phi} = \frac{|V_S|_{LL}\,|V_R|_{LL}}{|B|}\cos(\theta_B - \delta) - \frac{|A|\,|V_R|_{LL}^2}{|B|}\cos(\theta_B - \theta_A)$$

Theoretical Max Power $\rightarrow \theta_B = \delta$

$$P_{3\phi} = \frac{500 * 500}{164.6} - \frac{0.8137\,(500)^2}{164.6}\cos(85.412 - 1.09)$$

$$\boxed{P_{3\phi} = 1397\ MW}$$

$$I = \frac{P_{3\phi}}{\sqrt{3}\,V_{LL}\,(P.F)} = \frac{1397\,M}{\sqrt{3}\,(500k)(1)} = 1.613\,KA$$

from table Approx. Current carrying capacit $\Longrightarrow$ $1.11\,KA \Rightarrow 3 * 1.11\,KA = 3.33\,KA$

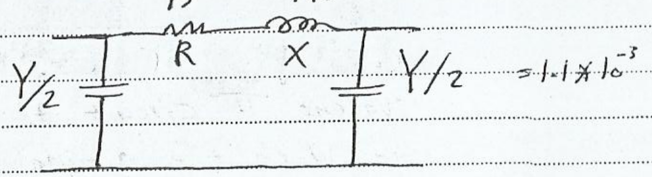
$\boxed{3.33\,KA > 1.613\,KA} \rightarrow$ Can be.

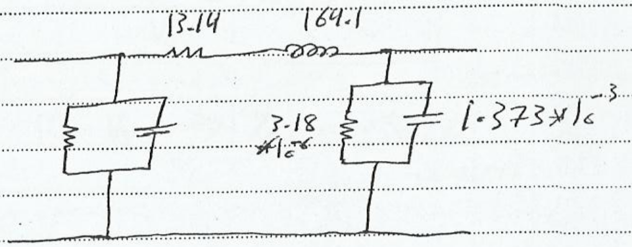
$$\frac{Y'}{2} = \frac{1}{Z_c}\tanh\left(\frac{\gamma L}{2}\right)$$

$$\frac{Y'}{2} = \frac{Y}{2}\,\frac{\tanh(\gamma L/2)}{\left(\frac{\gamma L}{2}\right)} \rightarrow \frac{\cosh(\gamma L) - 1}{\sinh(\gamma L)}$$

$$\frac{Y'}{2} = 1.137 * 10^{-6}\,\angle 89.84^\circ$$

$$\frac{Y'}{2} = 3.18 * 10^{-6} + j\,1.137 * 10^{-3}$$





relation between I_S & I_R is @ $V_S = V_R$

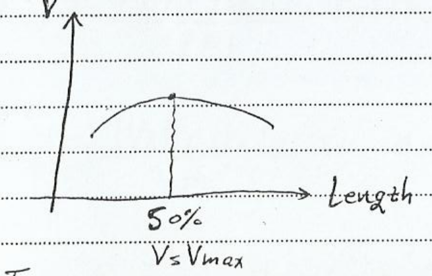
$$I_S = J \frac{1}{Z_c} \sin(\beta l)\, V_R + \cos(\beta l)\, I_R$$

$$V_R = J X_{Lsh} I_R$$

$$I_S = I_R \left[-\frac{1}{Z_c} \sin(\beta l) X_{Lsh} + \cos(\beta l) \right]$$

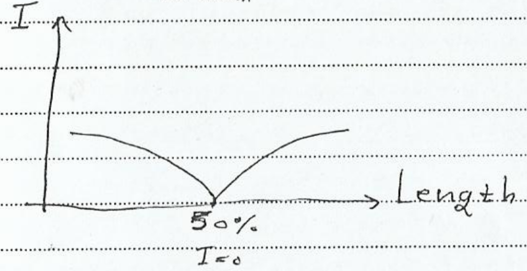
⋮

$$\boxed{I_S = -I_R}$$



$$\boxed{V_m = \frac{V_R}{\cos\left(\frac{\beta L}{2}\right)}}$$

$V_m \equiv$ Voltage at mid of the line & Will max Value



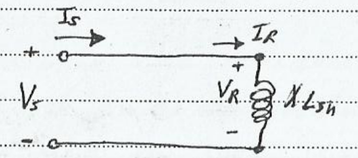
Subject:……………

Line Compensation :

[1] Shunt Compensation:

a.) Shunt Reactor Compensation :

Consider a reactor of reactance X_{Lsh} Connected at the receiving end (No load) of the line



$$I_R = \frac{V_R}{J X_{Lsh}}$$

$$V_S = \cos(\beta l)\, V_R + J Z_c \sin(\beta l)\, I_R$$

$$V_S = \left[\cos(\beta l) + \frac{Z_c}{X_{Lsh}} \sin(\beta l) \right] V_R$$

⋮

$$\boxed{X_{Lsh} = \frac{\sin(\beta l)}{\frac{V_S}{V_R} - \cos(\beta l)} Z_c}$$

For $V_S = V_R \Longrightarrow X_{Lsh} = \frac{\sin(\beta l)}{1 - \cos(\beta l)} Z_c$

$$Q_{1\phi} = V_{ph} I \sin(\theta) \quad ; \theta = 90$$

$$Q_{1\phi} = \frac{V_{ph}^2}{X} \longrightarrow \text{receiving Voltage}$$

$$Q_{1\phi} = \frac{(500/\sqrt{3})^2}{1519.5} = 54.84 \text{ MVAR}$$

$$Q_{3\phi} = 3\, Q_{1\phi} = 164.52 \text{ MVAR}$$

b) Shunt Capacitor Compensation:

$$P_{R3\phi} = \frac{|V_S|_{LL} |V_R|_{LL}}{|B|} \cos(\theta_B - \delta) - \frac{|A| |V_R|_{LL}^2}{|B|} \cos(\theta_B - \theta_A)$$

$$Q_{R3\phi} = \frac{|V_S|_{LL} |V_R|_{LL}}{|B|} \sin(\theta_B - \delta) - \frac{|A| |V_R|_{LL}^2}{|B|} \sin(\theta_B - \theta_A)$$

for lossless $\rightarrow \theta_A = 0 \; , \theta_B = 90$

Subject: .... / /

Example: السابق

For T.L of example (*)

a) Calculate The receiving end Voltage When line is terminated in an open circuit & is energized With 500KV at the Sending end.

b) Determine the reactance & MVAR of 3phase Shunt reactor to be installed at The receving end to keep the no load receiving end Voltage at the rated Value

Solution

$\beta l = 21.64 \quad Z_c = 290.43\ \Omega \quad A = 0.9295$

$V_{rated} = 500\text{ KV}$

a) $V_S = 500\text{ KV} \quad V_{R(NL)} = ?$

$$V_S = A V_R + \cancel{B I_R}$$

$$V_{R(NL)\phi} = \frac{V_S}{A} = \frac{500/\sqrt{3}}{0.9295} = 310.57\text{ KV}$$

$$V_{R(NL)LL} = \sqrt{3}\, V_{R(NL)\phi} = 537.9\text{ KV}$$

b)

$$X_{Lsh} = \frac{\sin(21.64)}{\frac{500KV}{500KV} - \cos(21.64)} = 1519.5\ \Omega$$

بلي نبه تتحقق عليها بعد إضافة X_{LSH}

Subject: .... / /

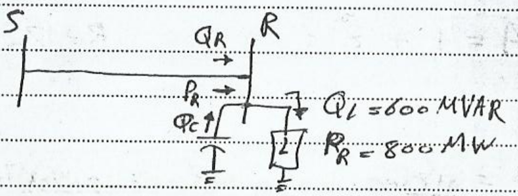
Only Series capacitors are installed at the mid point of the line providing 40 % compensation. Find V_s & % V.R

Solution

$Z_c = 290.43\,\Omega \qquad \beta l = 21.64^\circ$

a) $P_{R3\phi} = \dfrac{|V_s|_{LL}\,|V_R|_{LL}}{X} \sin(\delta)$

$Q_{R3\phi} = \dfrac{|V_s|_{LL}\,|V_R|_{LL}}{X} \cos(\delta) - \dfrac{|V_R|_{LL}^2}{X} \cos(\beta l)$



$800 = \dfrac{(500)(500)}{X} \sin(\delta)$

$X = Z_c \sin(\beta l) = 107.11\,\Omega$

$\delta = 20.04^\circ$

$Q_{R3\phi} = \dfrac{(500)(500)}{107.11} \cos(20.04) - \dfrac{(500)^2}{107.11} \cos(21.64) =$

$Q_{R3\phi} = 23.15$ MVAR

Subject: .... / /

Series Capacitor compensation:

* Series capacitors are connected in Series With the line.

* Usally located at the mid point of the line.

* Are used to reduce the Series reactance between the load & Supply point

- To improve transient & Steady State Stability.
- Minimum Voltage dip on Load buses.
- More economical loading.

$X_{Cser} \triangleq$ Series Capacitor reactance.

$\% \text{ Compensation} = \dfrac{X_{Cser}}{X}$

$P_{R3\phi} = \dfrac{|V_s|\,|V_R|}{X - X_{Cser}} \sin(\delta)$

Example:

A T.L in Ex.C) Supplies a load of 1000 MVA 0.8 P.f lagging at 500 KV.

a) Determine the MVAR & the capacitance of the Shunt capacity to be installed at the receiving end to keep The receving end Voltage at 500 kV When the line is energized with 500 KV at the Sending end.

$A = 1 + \frac{Z'Y'}{2} = 0.9577$

$B = Z' = J64.27\ \Omega$

$|V_R|_\phi = \frac{500KV}{\sqrt{3}}$

$I_R = \frac{1000}{\sqrt{3} * 500} = 1.1547\angle{-36.87}\ KA$

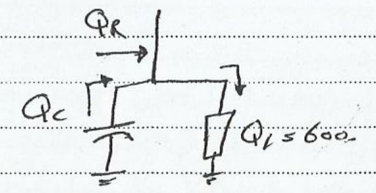
$V_s = AV_R + BI_R = 326.4\angle{10.47}\ KV$

$|V_s|_{LL} = \sqrt{3} * 326.4 = 565.4KV$

$V_{R(NL)} = \frac{V_s}{A} = \frac{565.4}{0.9577}$

$V.R = \frac{V_{R(NL)} - 500}{500} * 100 = 18\%$

Subject:.......................



$Q_c = \underset{Q_L}{600} - \underset{Q_R}{23.15} = 576.85\ MVAR_c$

$X_c = \frac{V^2}{Q_c} = \frac{(500)^2}{576.85} = 433.38\ \Omega$

$C = \frac{1}{WX_c} = \frac{1}{2\pi * 60 * 433.38} = 6.1\ \mu F$

b)

$A = 1 + \frac{Z'Y'}{2}$ $\quad B = Z'$

$40\% = \frac{X_{cser}}{X} \rightarrow X_{cser} = 0.4 * 107.11 = 42.84\ \Omega$

$C_{ser} = \frac{1}{WX_{cser}} =$

$X' = 107.11 - 42.84 = 64.27\ \Omega$

$Z' = J64.27\ \Omega$

$\cancel{A} \quad Y' = J\frac{2}{Z_c}\tan\left(\frac{BL}{2}\right) = J\frac{2}{290.43}\tan\left(\frac{21.64}{2}\right)$

$Y' = J0.001316\ S^1$

Subject:

Prob 5-15: Sadaat

The ABCD constants of lossless line 3Ø, 500kV T.L are $A = D = 0.86$, $B = J\,130.2\,\Omega$, $C = J\,0.002$ S

a) obtain the S.E.Q & V.R When the line delivers 1000 MVA at 0.8 lagging P.f at 500 KV to improve line performance, a Series capacitance are installed at both ends in each phase of T.L As results of this Compensated ABCD Const. become

$$\begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} = \begin{bmatrix} 1 & -J\frac{1}{2}X_c \\ 0 & 1 \end{bmatrix} \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} 1 & -J\frac{1}{2}X_c \\ 0 & 1 \end{bmatrix}$$

Where X_c is the total reactance of the Series Cap. Is $X_c = 100\,\Omega$

b) Determine the compensated ABCD

c) Determine the S.E.Q & V.R When line delives 1000 ~~kW~~ MVA & 0.8 lagging p.f at 500kV

Solution

$$\begin{bmatrix} 1 & -JX_c \\ 0 & 1 \end{bmatrix}$$ for Series capacitane

$$\begin{bmatrix} 1 & 0 \\ -B_L & 1 \end{bmatrix}$$ → for Shunt

(−) for reactance (+) for capacitance

$$\begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} = \begin{bmatrix} 1 & -J50 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} 1 & -J50 \\ 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} = \begin{bmatrix} 0.96 & J\,39.2 \\ J\,0.002 & 0.96 \end{bmatrix}$$

/ /

Prob 6-25 (Stevenson)

A 250 MVAR, 345KV, Shunt reactor is connected to the receiving end of a line of (Prob (6-16)) at No load calculated the ABCD constant

$$\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} 0.8180\angle 1.3 & 172.2\angle 84.2 \\ 0.001933\angle 90.4 & 0.8180\angle 1.3 \end{bmatrix}$$

* Solution *

$$\begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0.0021\angle -90 & 1 \end{bmatrix}$$

$$X_L = \frac{(345)^2}{250} = 470.1\,\Omega\angle 90$$

$$B_L = \frac{1}{X_L} = 0.0021\angle -90^\circ$$

Subject: .... / /

Ex 6-7 Stevenson:

Find The VR of Line of Ex ( ) When a shunt reactor is connected at the receiving end of line during No load conditions if the reactor compensates 70% of total shunt admittance of the line.

Solution

Previous Ex:

$y = 5.105 \times 10^{-6}\ S'/mi$

For entire line $B_C = 5.105 \times 10^{-6} \times 230 = 0.001174\ S'$

$B_L = 0.7 \times 0.001174 = 8.218 \times 10^{-4}\ S'$

$$\begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} = \begin{bmatrix} 0.8904\angle 1.34 & 186.78\angle 79.46 \\ 0.001131\angle 90.42 & 0.8904\angle 1.34 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 8.218\times 10^{-4}\angle -90 & 1 \end{bmatrix}$$

$$\begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} = \begin{bmatrix} 1.0411\angle -0.4 & 86.78\angle 79.46 \\ 4.01 \times 10^{-4}\angle 88.7 & 1.0411\angle -0.4 \end{bmatrix}$$

$$V.R\% = \frac{V_{RNL} - V_{RFL}}{V_{RFL}} \times 100 =$$

$$V_{RNL} = \frac{V_S}{A}$$

-18|

400Km

2400MW

$345\ kV \longrightarrow Z_c = 320\,\Omega$

الأفضل واحد $500\ kV \longrightarrow Z_c = 290\,\Omega$

$765\ kV \longrightarrow Z_c = 265\,\Omega$

$\lambda = 5000\,Km$

the practical line loadbility may be based on a loadangle of $35° \rightarrow \delta = 35°$

$|V_s| = 1\ p.u \qquad |V_R| = 0.9\ p.u$

Calculate the number of 3ϕ transmission circuits required for each Voltage

Solution

$$P = \frac{|V_s|_{p.u}\ |V_R|_{p.u}\ SIL}{\sin(\beta l)} \sin(\delta)$$

kV	Zc	SIL(MW)	P(MW)	N number of circuit
345	320 Ω	371.95	400	6
500	290 Ω	862.07	923.3	3
765	265 Ω	2208.4	2365	1

number of towers

6/2 3

3/2 2

1

ال tower

2 دائرة circuit

$\frac{2400}{400}$

$\frac{2400}{923.3}$

$\frac{2400}{2365}$

الأفضل هو 765KV بأخذ برج واحد ودائرة وحدة

Subject:

6-24|

The shunt admittance of a 300mi T.L is $y_c = j\,6.87\times10^{-6}\ S/mi$ Calculate ABCD constant of a shunt reactor That will compensate for 60 % of the total shunt admittance.

Solution

$B_L = 0.6 * 6.87 * 10^{-6} * 300 = 0.001237\ S^{-1}$

$$\begin{bmatrix} 1 & 0 \\ 0.001237\angle{-90} & 1 \end{bmatrix}$$

5-13 Sadaat | Look for it